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Influence of litter size and creep feeding on preweaning gain and influence of preweaning growth on growth to slaughter in barrows

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Influence of litter size and creep feeding on preweaning gain and influence of preweaning growth on growth to slaughter in barrows[1,2]

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ABSTRACT: The importance of birth-to-weaning average daily gain as a determinant of weight at a final age and yield of marketable pork was investigated. Treatments were imposed to create variation in birth-to-weaning ADG independent of birth weight. Newborn pigs were cross-fostered to create litters of four through 14 pigs/litter. Creep feed was offered to pigs from 5 d of age or during last 2 d before weaning at 13 to 20 d (average = 17 d). Growth rate and carcass dissection data were obtained from 195 barrows that were slaughtered at an average age of 170 d (SD = 7.5), weight of 109 kg (SD = 10.5). All traits measured were influenced by birth dam and sire ($P < 0.01$). Quadratic and cubic effects ($P < 0.09$) of litter size on birth-to-weaning ADG and weaning weight were different between the creep feeding treatments. Data revealed a positive influence ($P < 0.04$) of creep feeding from 5 d of age on birth-to-weaning ADG and weaning weight in larger size (>8) litters. Importance of the independent variables birth weight, birth-to-weaning ADG, weaning weight, and birth weight plus birth-to-weaning ADG in determination of measures of postweaning growth and yield of marketable pork were examined by step-down regression analysis. Initial models included the linear and quadratic effects of the independent variables. In general, R^2 for models ranked birth weight < birth-to-weaning ADG < d-17 weaning weight < birth weight + birth-to-weaning ADG. The R^2 of models for BW at 170 d of age were 0.11 ($P < 0.01$) using birth weight as the independent variable, 0.16 ($P < 0.01$) using birth-to-weaning ADG, 0.19 ($P < 0.01$) using d-17 weaning weight, and 0.21 ($P < 0.01$) using birth weight + birth-to-weaning ADG. The model for effect of birth-to-weaning ADG on BW at 170 d of age indicated that a 10-g advantage in birth-to-weaning ADG produced a 0.94-kg advantage in BW at 170 d of age. Positive relationships ($P < 0.05$) between birth-to-weaning ADG and measures of postweaning growth and carcass yield suggest management practices that increase birth-to-weaning ADG may be advantageous in pork production.

Key Words: Birth Weight, Carcasses, Growth, Pigs, Weaning

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Introduction

The contention that "pigs that are the heaviest at weaning reach market weights more quickly." (Ensminger, 1951) has been supported by research results (Boaz and Elsley, 1962; Mahan, 1993; Mahan et al., 1998) and producer observations. An extension of this concept is that management practices that increase weaning weight will decrease time to market. Several studies support the hypothesis that it is advantageous to have pigs weigh more at weaning, and, thus, it may be advantageous to increase the lactational capability of sows to increase pig growth preweaning (Boaz and Elsley, 1962; Mahan, 1993; Mahan et al., 1998). These studies examined pigs weaned at ages (28 to 56 d) later than those used in current swine production (10 to 21 d) and slaughtered at weights less than the current standard of 110 to 120 kg. When pigs are weaned at 10 to 21 d of age, moderate nutrient restriction may influence birth-to-weaning rate of gain and weaning weight but may not have an effect on days to slaughter due to a compensatory gain expressed when pigs have ad libitum access to feed in the nursery and finishing. Although pigs that are heavier at weaning attain slaughter weight at an earlier age, their weaning weight advantage may not solely reflect better preweaning nutrition. Pigs heavier at weaning were heavier at birth, and greater birth weight may explain advantage in weaning weight (Boaz and Elsley, 1962; Mahan,

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1993; Mahan et al., 1998). Pigs heavier at birth may have superior growth potential, evidenced by their superior prenatal growth, and their greater size may be an advantage while nursing the sow.

The objective of the current study was to manage preweaning access to nutriment through alteration of litter size and availability of creep feed and examine the effect of birth weight, birth-to-weaning rate of gain (ADG), and weaning weight on postweaning growth and yield of marketable pork.

Materials and Methods

All animal procedures were reviewed and approved by the U.S. Meat Animal Research Center Animal Care and Use Committee.

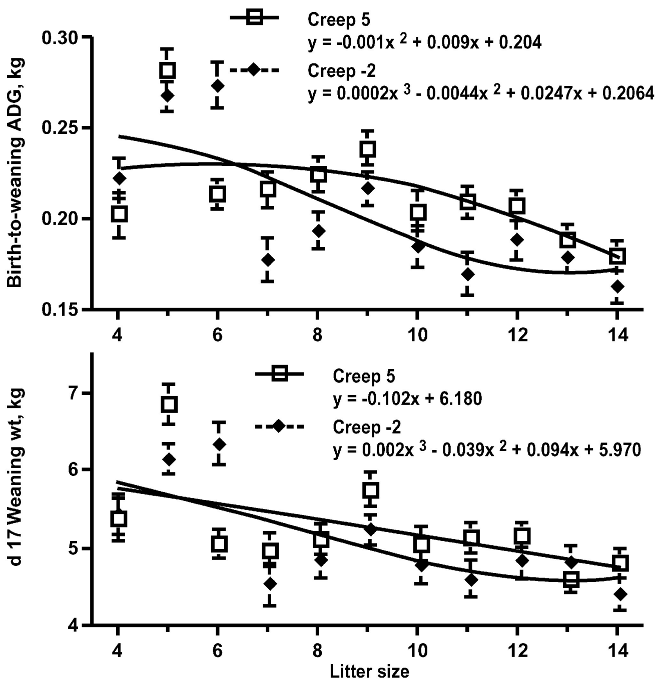
The study used offspring of crossbred White (American Landrace × Yorkshire) first- and second-parity sows mated to crossbred White (American Landrace × Yorkshire) boars born in a 21-d farrowing group. Farrowings occurred in a six-room, 20-crates-per-room, enclosed, temperature-controlled farrowing facility. Average birth date was November 11 (SD = 2.6 d). Each morning during farrowing, pigs born in the previous 24 h were identified, weighed, tails docked, navels dipped, and eyeteeth cut. This was considered birth date, d 0. After newborn pigs were processed by farrowing house personnel, litters were selected for inclusion in the study. Litters were chosen for inclusion in the study based on number of healthy pigs available and the opportunity to create litters of the desired sizes. Pigs from a minimum of four litters were included in the study on each day of cross-fostering. Pigs, 415 males and females, were assigned to sows to create 48 litters of 4 to 14 pigs. An attempt was made to have uniformity in body weight among the litters created on each day and at least four males in each created litter. The goal was to obtain four to six litters of each litter size and a minimum of 12 males in each litter size. Excess females were assigned to sows not in the study. The number of pigs in these created litters is referred to as *assigned litter size.* Assigned litter size did not exceed count of the sow's functional teats. In addition to the effect of assigned litter size on birth-to-weaning ADG, the effect of creep feeding was measured. A commercial creep feed (Early Edge, Land-O-Lakes, Arden Hills, MN) was offered from 5 d of age until weaning (**Creep 5**) or from 2 d before weaning until weaning (**Creep –2**). Creep feed was fed on the floor. At 10 d of age, males were castrated. Twice a week, when pigs were 13 to 20 d of age, sows were removed from the farrowing crates. This was considered weaning. Weaning weights were adjusted to average weaning age, 17 d, by within-pig linear regression. All pigs within a 20-crate farrowing room were weaned and moved to the nursery facility on a single day. In the nursery, multiple litters were combined within nursery pens. However, each nursery pen contained only pigs from the same assigned litter size and creep feed treatment. Eight to 10 pigs were assigned to a nursery pen. At 64 to 73 d of age (average 67 d), barrows were moved to a finishing facility and penned 10/pen. Barrows were stratified by weight for assignment to finishing pens to reduce within-pen variation in weight at the start of the finishing period. Heavier weight pigs were penned together and lighter weight pigs were penned together, to reduce within-pen variation in weight at projected slaughter weight, 113 kg. Average within-finishing pen SD was 3.2 kg at the start of the finishing period. Throughout the study, pigs were fed standard corn-soybean meal grower-finisher diets that met or exceeded recommendations (NRC, 1998). Pigs were weighed at approximately 4-wk intervals and at times of transfer from one facility to another, e.g., farrowing to nursery or nursery to finishing. All pigs within a finisher pen were slaughtered at the same time. At an average weight of 109.3 kg (SD = 11.3) and age of 170.3 d (SD = 7.5), the barrows were transported to the abattoir for slaughter. Twenty-four hours after slaughter, carcass data were collected. Carcass data included chilled carcass weight; carcass length; untrimmed weights of the Boston butt, picnic ham, loin, ham, and belly; and trimmed weights of Boston butt, picnic ham, loin, and ham (NAMP, 1988). Trimmed weights of Boston butt, picnic ham, loin, and ham were summed to obtain the value "trimmed four lean cuts." Slaughter live weight was adjusted by within-pig linear regression of finishing period weights to 170 d of age to obtain d-170 BW. The carcass weights were similarly adjusted to d-170 BW.

Only data from barrows was included in the analyses addressing the objective of the study. The females were not available for the finishing-slaughter proportion of the study. Analyses of variance and regression analyses were performed using the general linear models (GLM) procedure of SAS (SAS Inst. Inc., Cary, NC).

Results and Discussion

The objective of cross-fostering pigs—the generation of the created litters—was to reduce the correlation between litter size and birth weight. In created litters, the correlation between birth weight and assigned litter size was small (r = 0.07, $P = 0.15$, n = 415). In contrast, there was a significant correlation between birth weight and birth litter size in natural litters, litters that experienced no cross-fostering, born in the same farrowing group and facility (r = –0.13, $P < 0.01$, n = 582). Cross-fostering reduced the confounding of litter size and birth weight.

Figure 1 presents the least-squares means for birth-to-weaning ADG and d-17 weaning weight for each assigned litter size and creep feeding treatment. Each creep feeding treatment was analyzed separately with assigned litter size as the source of variation in the model. Contrasts were used to test linear, quadratic, and cubic effects of assigned litter size. Birth-to-weaning ADG was influenced by assigned litter size in a quadratic ($P = 0.09$) manner in pigs offered creep feed



Contrasts for litter size	Creep 5	Creep -2	Creep 5	Creep -2
	P	P	P	P
Linear	0.01	0.01	0.01	0.01
Quadratic	0.09	0.11	0.97	0.09
Cubic	0.45	0.03	0.31	0.07

Figure 1. Effect of assigned litter size and creep feeding treatment on birth-to-weaning ADG and d-17 weaning weight. Pigs were offered creep feed from 5 d of age until weaning (Creep 5) or for the last 2 d before weaning (Creep –2). The points are the LS means (± SE). Analyses of variance were performed for each creep feeding treatment and effect of litter size examined by nonorthogonal contrasts. The results are presented in the table at the bottom of the figure. The lines in the panels are the fitted polynomials at the power indicated by results from fitting nonorthogonal contrasts. The equations for those fitted polynomials are presented in the legends.

from 5 d of age (Creep 5) and in a cubic (P = 0.03) manner in pigs offered creep feed for only 2 d before weaning (Creep –2). Inflection points in cubic curve for birth-to-weaning ADG in the Creep –2 pigs are at assigned litter sizes of 5 to 6 and about 11. This curve suggests that nutrient availability, expressed as assigned litter size, was in excess at four and five pigs per litter, determined pig growth rate in litters greater than five pigs per litter, and the effect of limited nutrient availability diminished as litter size increased. A comparison of the Creep 5 and Creep –2 curves suggests that the added nutrient availability in the Creep 5 group allowed more full expression of growth potential in litters larger than eight pigs per litter. These effects on birth-to-weaning ADG were reflected in weaning weight at 17 d of age. Although creep feed consumption was not recorded in the present study, results suggest that pigs in larger litters consumed sufficient creep feed after 5 d of age to affect preweaning growth rates.

Four hundred fifteen pigs were initially assigned to 48 created litters in the study. Twenty-six pigs, 6.3%, died before weaning. No litter lost more than two pigs, and no litter smaller than nine lost more than one pig. Assigned litter size did not effect death loss (P > 0.67). One hundred and ninety-five barrows completed the study. Only barrows that completed the study are included in the subsequent analyses. The mean (± SD) birth weight, birth-to-weaning ADG, and d-17 weaning weight were 1.60 ± 0.32 kg, 0.213 ± 0.047 kg/d, and 5.23 ± 0.95 kg, respectively. Birth dam influenced (P < 0.01; R^2 = 0.49 to 0.71) all measures of performance (Table 1). Influence of sire on performance measures was also significant (P < 0.01, R^2 = 0.16 to 0.21), though less than that of the dam, indicating the effect of prenatal maternal environment.

Table 2 presents regression analyses of the relationship of the variables considered independent variables, that is, birth weight, birth-to-weaning ADG, d-17 weaning weight, and birth weight plus birth-to-weaning ADG, with measures of postweaning growth and yield of marketable pork, the dependent variables. Parameters of independent variables that remained in the step-down regression models were different than zero (P ≤ 0.05). The generalized ranking of the models based on R^2 is birth weight < birth-to-weaning ADG < d-17 weaning weight < birth weight plus birth-to-weaning ADG for all dependent variables (Table 2). Multiple-trait models that initially included birth weight, birth-to-weaning ADG, their interaction, and their quadratic

Table 1. Influence of birth dam and sire on variables measured

	Influence of birth dam[a]		Influence of sire[b]	
Variable	P	R^2	P	R^2
Birth wt, kg	<0.01	0.69	<0.01	0.21
Birth-to-weaning ADG, kg	<0.01	0.71	<0.01	0.19
d-17 weaning wt, kg	<0.01	0.69	<0.01	0.20
Postweaning ADG, kg	<0.01	0.47	<0.01	0.17
d-170 BW, kg	<0.01	0.51	<0.01	0.17
Chilled carcass wt, kg	<0.01	0.49	<0.01	0.16
Trimmed four lean cuts, kg	<0.01	0.50	<0.01	0.19

[a]Fifty-one birth dams that contributed an average of 3.8 (range, 2 to 8) barrows to the study.
[b]Fifteen boars that sired an average of 13 (range, 3 to 34) barrows used in the study.

Table 2. Step-down regression analyses of the relationship of birth weight, d-17 weaning weight, birth-to-weaning ADG, and birth weight plus birth-to-weaning ADG on postweaning measures of growth performance

Dependent variable (mean ± SD)	Intercept and slope estimates of the regression models[a]								
Independent variable(s)	Intercept	Birth wt	Birth wt^2	b-wADG	b-wADG^2	Wean wt	Wean wt^2	brwt × bwADG[b]	R^2
d-170 BW, kg (109.3 ± 11.3)									
Birth wt, kg	54.84 ± 15.11[c] (0.01)[d]	59.25 ± 18.90 (0.01)	−15.16 ± 5.78 (0.01)	—	—	—	—	—	0.11 (0.01)
Birth-to-weaning ADG, kg/d	98.33 ± 3.43 (0.01)	—	—	93.76 ± 15.72 (0.01)	NS[e]	—	—	—	0.16 (0.01)
d-17 weaning wt, kg	82.53 ± 4.09 (0.01)	—	—	—	—	5.12 ± 0.077 (0.01)	NS	—	0.19 (0.01)
Birth wt + birth-to-weaning ADG, kg	47.73 ± 14.36 (0.01)	50.50 ± 17.86 (0.01)	−13.49 ± 5.47 (0.01)	78.21 ± 15.96 (0.01)	NS	—	—	NS	0.21 (0.01)
Postweaning ADG, kg (0.634 ± 0.071)									
Birth wt, kg	0.348 ± 0.097 (0.01)	0.368 ± 0.121 (0.01)	−0.097 ± 0.037 (0.01)	—	—	—	—	—	0.09 (0.01)
Birth-to-weaning ADG, kg/d	0.576 ± 0.022 (0.01)	—	—	0.489 ± 0.102 (0.01)	NS	—	—	—	0.11 (0.01)
d-17 weaning wt, kg	0.539 ± 0.027 (0.01)	—	—	—	—	0.027 ± 0.005 (0.01)	NS	—	0.13 (0.01)
Birth wt + birth-to-weaning ADG, kg	0.312 ± 0.093 (0.01)	0.324 ± 0.111 (0.01)	−0.088 ± 0.036 (0.01)	0.400 ± 0.104 (0.01)	NS	—	—	NS	0.16 (0.01)
Chilled carcass wt, kg (67.89 ± 7.62)									
Birth wt, kg	32.93 ± 10.28 (0.01)	37.90 ± 12.86 (0.01)	−9.65 ± 3.93 (0.02)	—	—	—	—	—	0.11 (0.01)
Birth-to-weaning ADG, kg/d	56.41 ± 2.38 (0.01)	—	—	53.86 ± 10.91 (0.01)	NS	—	—	—	0.11 (0.01)
d 17 weaning wt, kg	52.03 ± 2.84 (0.01)	—	—	—	—	3.04 ± 0.53 (0.01)	NS	—	0.14 (0.01)
Birth wt + birth-to-weaning ADG, kg	29.02 ± 9.98 (0.01)	33.09 ± 12.47 (0.01)	−8.72 ± 3.80 (0.01)	43.02 ± 11.09 (0.01)	NS	—	—	NS	0.17 (0.01)
Trimmed four lean cuts, kg (49.09 ± 5.48)									
Birth wt, kg	20.16 ± 7.30 (0.01)	31.68 ± 9.13 (0.01)	−8.17 ± 2.79 (0.01)	—	—	—	—	—	0.13 (0.01)
Birth-to-weaning ADG, kg/d	39.46 ± 1.68 (0.01)	—	—	45.19 ± 7.68 (0.01)	NS	—	—	—	0.15 (0.01)
d 17 weaning wt, kg	36.00 ± 1.99 (0.01)	—	—	—	—	2.50 ± 0.37 (0.01)	NS	—	0.19 (0.01)
Birth wt + birth-to-weaning ADG, kg	16.80 ± 6.95 (0.02)	27.55 ± 8.69 (0.01)	−7.39 ± 2.65 (0.01)	36.89 ± 7.73 (0.01)	NS	—	—	NS	0.22 (0.01)

[a]The initial models were included the linear and quadratic effects of the independent variable and where appropriate the interaction among the two independent variables with the independent variables treated as continuous variables. Quadratic and interaction terms that were not significant ($P > 0.05$) were deleted in a sequential step-down manner.

[b]Parameter for the interaction of birth weight and birth-to-weaning ADG (brwt × bwADG).

[c]Estimate of the parameter ± standard error of the estimate.

[d]Probability the estimate is not different than zero.

[e]Quadratic or interaction term was initially included in the model and when determined to be nonsignificant ($P > 0.05$) it was removed. Nonsignificant linear terms removed only after removal of the quadratic or interaction terms.

terms were superior to the single-trait models in the prediction of the postweaning growth and carcass characteristics measured (Table 2).

The contention that “pigs that are the heaviest at weaning reach market weights more quickly” (Ensminger, 1951) is supported herein by positive relationships among birth-to-weaning ADG, d-17 weaning weight, and postweaning rates of gain. Much of the published data supporting that contention is from studies conducted when standard pork production practices were different, that is, later weaning ages and lighter slaughter weights. When weaning occurred at 56 d of age, significant relationships between weaning weight and market weight were to be expected because weaning weight accounted for approximately 15% of the 80-kg market weight. Herein, weaning weight accounts for less than 5% of slaughter weight, 109 kg. Recently, Cabrera et al. (2002) reported on pigs weaned at 19 d of age. Their findings agree with the results presented herein and earlier reports of a positive relationship between weaning weight and postweaning growth rate in pigs weaned at later ages (Boaz and Elsley, 1962; Mahan, 1993; Mahan et al., 1998). Pigs in the Cabrera et al. (2002) report that were heavier at weaning achieved market weight sooner and produced more marginal revenue per pig. However, pigs that were heavier at weaning had been heavier at birth. Greater birth weight may reflect superior genetics and/or prenatal maternal environment. Greater birth weight may provide a competitive advantage preweaning. Even in the presence of major changes that have occurred in swine production practices, there are still production advantages to greater rates of birth-to-weaning ADG.

These findings, positive influence of birth-to-weaning ADG on postweaning growth and yield of marketable pork, suggest that limited nutrient availability during the birth-to-weaning period, even in pigs weaned at an early age, 13 to 20 d, does influence the expression of growth potential to slaughter weight. Birth-to-weaning ADG accounted for 16% of the variation in BW at 170 d of age (Table 2). Some of the advantage in birth-to-weaning ADG is due to genetics and prenatal environment. However, this effect is not large. Regression of birth-to-weaning ADG on birth weight reveals that birth weight accounts for about 8% of the variation in birth-to-weaning ADG ($R^2 = 0.084$, $P < 0.01$) in these data. The major determinant of birth-to-weaning ADG in these data appears to be nutrient availability, expressed as litter size and creep feeding treatment. Nutrient availability accounted for about one-fourth of the variation in birth-to-weaning ADG ($R^2 = 0.24$, $P < 0.01$). Nutrient availability in combination with prenatal environmental influences and genetic composition determine birth-to-weaning ADG. Birth-to-weaning ADG, and by extension, weaning weight, influences postweaning growth performance and yield of marketable pork. Limited nutrient availability preweaning may have long-term effects on postweaning performance.

Potential growth rate of nursing pigs can be as great as 450 g/d, a growth rate that would require 2 kg of sow’s milk per day (King, 2000). The feed intake required to maintain such a level of lactational output would be about 14 kg/d (NRC, 1988). Sows cannot consume this quantity of feed and would need to mobilize body reserves, as many do with the current levels of lactational output, levels of lactational output that are less than what is required for expression of maximal growth potential by nursing pigs (NRC, 1998). Sows in greater nutrient deficit during lactation and those nursing larger litters tend to have longer weaning-to-estrus intervals (Koketsu and Dial, 1997; Fahmy et al., 1979). Whereas data herein indicates maximizing birth-to-weaning ADG may improve postweaning growth and yield of marketable pork, it does not provide sufficient information to make a strong argument, $R^2 < 0.22$, in support of expenditure of resources to increase birth-to-weaning ADG and thus weaning weight in pigs weaned at 13 to 20 d of age. The desirability of increasing birth-to-weaning ADG is uncertain, particularly if it is achieved through increased lactational production by sows. Among costs of increased lactational production by sows is additional feed cost due to increased quantity, and possibly quality; increased labor costs due to more frequent feeding; increased mobilization of body reserves by the sow during lactation; and increased weaning-to-estrus interval due to decreased body reserves at weaning.

Implications

Birth-to-weaning average daily gain and weaning weight are decreased with an increased number of pigs nursing a sow. Providing creep feed from 5 d of age increases birth-to-weaning average daily gain and weaning weight at larger litters (i.e., greater than eight pigs). Increasing birth-to-weaning average daily gain results in increased postweaning growth rate and yield of marketable pork.

Literature Cited

Boaz, T. G., and F. W. H. Elsley. 1962. The growth and carcass quality of bacon pigs reared to different weights at 56 days old. Anim. Prod. 4:1–24.

Cabrera, R., S. Jungst, R. D. Boyd, M. E. Johnson, E. Wilson, and J. L. Usry. 2002. Impact of pig weight at weaning. II. post-weaning growth and economic assessment of weights ranging from 4.1 to 8.6 kg. J. Anim. Sci. 80(Suppl. 1):199. (Abstr.)

Ensminger, E. M. 1951. Animal Science. Interstate Publishers, Danville, IL.

Fahmy, M. H., W. B. Holtman, and R. D. Baker. 1979. Failure to recycle after weaning, and weaning to oestrus interval in crossbred sows. Anim. Prod. 29:193–202.

King, R. H. 2000. Factors that influence milk production in well-fed sows. J. Anim. Sci. 78(Suppl. 3):19–25.

Koketsu, Y., and G. D. Dial. 1997. Factors associated with prolonged weaning-to-mating interval among sows on farms that wean early. J. Am. Vet. Med. Assoc. 211:894–898.

Mahan, D. C. 1993. Effect of weight, split-weaning, and nursery feeding programs on performance responses of pigs to 105 kilograms body weight and subsequent effects on sow rebreeding interval. J. Anim. Sci. 71:1991–1995.

Mahan, D. C., G. L. Cromwell, R. C. Ewan, C. R. Hamilton, and J. T. Yen. 1998. Evaluation of the feeding duration of phase 1 nursery diet to three-week-old pigs of two weaning weights. J. Anim. Sci. 76:578–583.

NAMP. 1988. The Meat Buyers Guide. North American Meat Processors Association, Reston, VA.

NRC. 1988. Nutrient Requirements of Swine. 9th rev. ed. Natl. Acad. Press, Washington, DC.

NRC. 1998. Nutrient Requirements of Swine. 10th rev. ed. Natl. Acad. Press, Washington, DC.